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COMPONENT AND METHOD FOR ITS MANUFACTURE

Background Information

The present invention relates to a component, in particular a sensor element, having a substrate used as support and a silicon layer, in which the component structure is formed. The component structure includes at least one fixed element, in particular an electrode. Furthermore, the present invention relates to a method for manufacturing such a component.

In practice, many components and particularly sensor elements having movable structural elements are manufactured from so-called SOI (silicon on insulator) wafers. The structure of an SOI wafer normally includes a monocrystalline silicon layer connected to a silicon substrate via a silicon oxide layer. The component structure is formed in the monocrystalline silicon layer. Movable structural elements are exposed by removing the silicon oxide layer under these structural elements. For this reason, the silicon oxide layer is also called a sacrificial layer. The sacrificial layer is usually removed in an etching process, in which normally other parts of the component structure are undercut as well. This proves problematic in practice, especially with regard to fixed elements of the component structure such as electrodes, for example. That is to say, in sacrificial layer etching, the silicon oxide underneath the electrodes is attacked as well. To date, it is only possible to ensure that the electrodes are mechanically anchored to the silicon substrate if the electrodes have certain minimum dimensions, so that they are not completely undercut during the etching of the sacrificial layer.

Summary of the Invention

The present invention provides a concept for anchoring fixed structural elements and particularly for anchoring electrodes for components whose component structure is formed in a silicon layer on top of a substrate used as support. This concept is especially suitable for components manufactured from SOI wafers.

According to the present invention, the fixed element of the component structure is mechanically connected to the substrate via at least one anchoring element made of an anchoring material and extending through the silicon layer. In the case of an SOI wafer, the anchoring element extends through the silicon layer and the sacrificial layer of the SOI wafer. To this end, in the area of the surface of the fixed element, at least one recess is made in the silicon layer, which extends through the entire silicon layer and the sacrificial layer down to the substrate. The recess is then filled with an anchoring material, so that the fixed element is mechanically connected to the substrate via the anchoring element that is thereby created.

According to the present invention, it was recognized that it is possible to connect fixed elements of the component structure mechanically to the substrate with the aid of anchoring elements. The sole prerequisites for a reliable anchoring are that the anchoring material is of sufficient mechanical strength and is not substantially attacked by the processes used in manufacturing the component, e.g. by the etching of the sacrificial layer. The anchoring concept according to the present invention allows for the implementation of the smallest component structures, which are nevertheless firmly connected to the substrate, and thus contributes to the miniaturization of components.

Fundamentally, there are various possibilities for implementing a component according to the present invention and for developing and refining the method manufacturing such a component of the present invention.

With regard to miniaturizing the component as much as possible and anchoring it reliably, it proves advantageous to situate the anchoring element essentially at the center of the surface of the fixed element. To this end, the silicon layer and, in the case of an SOI wafer, the sacrificial layer must be patterned accordingly.

Anisotropic etching processes such as trenching, for example, are suitable for pattering the silicon layer, since anisotropic etching processes facilitate the creation of relatively deep yet narrow recesses. In this manner, it is possible to minimize the space required for the component structure. Simply by continuing the anisotropic etching process for patterning the silicon layer, the sacrificial layer can be patterned accordingly. Alternatively, the sacrificial layer may also be patterned using an isotropic etching process, which is especially advantageous with regard to the formation of the anchoring element. Namely, during the isotropic etching of the sacrificial layer, the edge region of the recess in the silicon layer is undercut as well. The subsequent filling of the recess extending through the silicon layer and the sacrificial layer produces an anchoring element, which, on account of its barbed structure as well as on account of the enlarged surface connecting it to the substrate, ensures a particularly strong anchoring of the fixed element.

In one advantageous variant of the method according to the present invention, the anchoring material is deposited on the

silicon layer after the silicon layer and the sacrificial layer have been patterned. This results in the growth of the anchoring material on the substrate in the area of the recess, which fills the recess and forms an anchoring element. In addition, the silicon layer is coated with anchoring material. Normally, this coating is at least partially removed again, taking into account the function of the relevant structural elements of the component.

For an anchoring element that is used to anchor an electrode, advantageously an electrically non-conductive anchoring material is chosen to prevent a short ciruit via the substrate of the component. Silicon carbide SiC and especially silicon-rich silicon nitride SiN have proven successful in this regard as anchoring materials. The above-mentioned coating with anchoring material may either extend only over a region of the electrode's surface around the anchoring element or essentially over the entire surface of the electrode. In this case, however, at least one contact hole for the electrode must be formed in the coating. The contact hole is advantageously located outside of the region of the anchoring element, so that the mechanical anchoring of the electrode and its electrical connection are spatially decoupled.

A particularly advantageous variant of the component according to the present invention features a cap diaphragm formed over the component structure, via which electrical contact is established with the electrodes of the component structure. The cap diaphragm may also be mechanically connected to the substrate via the anchoring elements.

Brief Description of the Drawing

As discussed in detail earlier, there are various possibilities for advantageously shaping and refining the

teaching of the present invention. For this purpose, reference is made to the claims dependent on the independent claims as well as to the following description of an exemplary embodiment of the present invention based on the drawings.

Fig. 1 shows the perspective representation of a sensor structure according to the present invention having movable and fixed elements,

Fig. 2 shows a sectional view of the sensor structure represented in Fig. 1 following the application of a second sacrificial layer for producing a cap diaphragm,

Fig. 3 shows the sensor structure represented in Fig. 2 following the patterning of the second sacrificial layer,

Fig. 4 shows the sensor structure represented in Fig. 3 following the application and patterning of a diaphragm layer,

Fig. 5 shows the sensor structure represented in Fig. 4 following the removal of the second sacrificial layer.

Description of the Exemplary Embodiment

The exemplary embodiment for a component according to the present invention represented in the figures is a sensor element 1 for recording accelerations.

Sensor element 1 is manufactured from an SOI wafer containing a monocrystalline silicon layer 2, which is connected via a sacrificial layer 3 to a substrate 4, in this case a silicon substrate. Sacrificial layer 3 is here a silicon oxide layer. The sensor structure is formed in monocrystalline silicon layer 2 and includes movable elements 5, upon which an acceleration may act. The deflections of movable elements 5

from their rest position are recorded with the aid of electrodes 6, which are fixed elements of the sensor structure.

According to the present invention, each electrode 6 is mechanically connected to substrate 4 via one anchoring element 7. To this end, anchoring elements 7 are positioned essentially at the center of the respective electrode surface and extend through entire silicon layer 2 and through sacrificial layer 3 down to substrate 4. Anchoring elements 7 are formed of an electrically non-conductive anchoring material. In the exemplary embodiment described here, silicon-rich silicon nitride SiN is used as anchoring material, since it is also resistant to the HF vapor etching of sacrificial layer 3, and since anchoring elements made of SiN are of sufficient mechanical strength.

The production of the sensor structure represented in Fig. 1 begins with the creation of the recesses for anchoring elements 7 of electrodes 6 in silicon layer 2. Here, an anisotropic etching process such as trenching was used for this purpose. Subsequently, the silicon oxide in the region of these recesses is also removed. In the exemplary embodiment shown here, an anisotropic etching process was also used for this purpose, since the edge regions of the recesses in silicon layer 2 were not undercut. It should be noted at this point that it is also possible to remove sacrificial layer 3 in the region of the recesses using an isotropic etching process, so that the edge regions of the recesses in silicon layer 2 are undercut. This variant of the method according to the present invention can be used to produce anchoring elements that extend in the area of sacrificial layer 3 to below silicon layer 2, thus creating a barbed structure.

The recesses, which then extend through entire silicon layer 2 and sacrificial layer 3 down to substrate 4, are now filled with the anchoring material. For this purpose, SiN is deposited on silicon layer 2 in a deposit step, so that it grows on substrate 4 in the area of the recesses. A sufficiently large amount of SiN must be deposited so that the recesses are subsequently closed. At the same time, silicon layer 2 is coated with anchoring material. In the exemplary embodiment shown here, this SiN coating 8 was patterned in such a way that it remains on the surfaces of the electrodes. The electrically insulating SiN on the surfaces of the electrodes allows for an electrically insulated mechanical connection of the electrodes to a subsequently produced diaphragm layer, which is actually used for the electrical connection of electrodes 6 of sensor element 1. To allow for an electrical contact between electrodes 6 and a connection in the diaphragm layer, a contact hole 9 is formed for every electrode 6 in corresponding SiN coating 8. Contact opening 9 is located away from the area of anchoring element 7 so as to decouple the electrical contacting and the mechanical anchoring of electrode 6.

After anchoring elements 7 have been produced as described above, the functional sensor structure is introduced into silicon layer 2, likewise using an anisotropic etching process, for example, by trenching. In so doing, both movable elements 5 as well as fixed elements of the sensor structure such as electrodes 6 are defined. In a further process step the etching of the sacrificial layer movable elements 5 are exposed. To this end, sacrificial layer 3 is removed not only under movable elements 5, but electrodes 6 are undercut as well. However, since the anchoring material is resistant to the HF vapor etching used for removing silicon oxide layer 3, electrodes 6 remain mechanically firmly connected to substrate 4 via anchoring elements 7.

The electrical connection of electrodes 6 of a sensor element 1, as represented in Fig. 1, may be effected via a thin-film diaphragm which additionally also seals the sensor structure. As an alternative to such thin-film packaging, the electrical connection may also be achieved via a so-called cap diaphragm, which will be explained in more detail below in light of Figures 2 to 4.

To produce a cap diaphragm, a second sacrificial layer 11, which in the present case is also made of silicon oxide, is applied to the sensor structure depicted in Fig. 1. Second sacrificial layer 11 closes the interstices between individual elements 5 and 6, thereby creating a continuous surface, as shown in Fig. 2.

Subsequently, second sacrificial layer 11 is patterned in such a way that openings 12 and 13 are produced in sacrificial layer 11 wherever the diaphragm layer is to have direct contact with silicon layer 2 (openings 12) or with SiN coating 8 (openings 13). Fig. 3 accordingly shows openings 12 in the area of contact holes 9 and openings 13 in the area of the coated surfaces of the electrodes.

A diaphragm layer 14 made of polysilicon or SiGe, for example, is then produced on top of patterned second sacrificial layer 11. Following the application of a starting layer, polysilicon may simply be grown epitactically. Subsequently, diaphragm layer 14 is patterned, which in the case of a polysilicon layer may also be achieved by trench etching. On the one hand, this patterning produces openings 15 for the sacrificial layer etching, during which at least second sacrificial layer 11 and possibly also first sacrificial layer 3 may be removed. On the other hand, the patterning of diaphragm layer 14 produces openings 16, which electrically insulate the contact

lead-throughs between functional silicon layer 2 and diaphragm layer 14 in the area of contact holes 9 from the remaining areas of diaphragm layer 14. These openings 16 are referred to below as insulating trenches. Sensor element 1 featuring the diaphragm layer patterned in this way is represented in Fig. 4.

At this point, second sacrificial layer 11 and, if it has not yet been done, also first sacrificial layer 3 may be removed again, in order to expose movable elements 5 of the sensor structure. HF vapor etching is normally used for this purpose. As was already mentioned, the anchoring material SiN is not attacked by HF vapor etching, so that electrodes 6 remain mechanically rigidly connected both to substrate 4 as well as to diaphragm layer 14 via anchoring elements 7. Fig. 5 shows sensor element 1 having a cap diaphragm 14 produced in this manner. On the one hand, cap diaphragm 14 is in immediate contact with electrodes 6 via contact holes 9, thus enabling their electrical connection. On the other hand, cap diaphragm 14 is mechanically connected to substrate 4 via SiN coating 8 of the electrode surfaces and via anchoring elements 7, so that cap diaphragm 14 is anchored as well.

An electrode 6, electrically connected via cap diaphragm 14, must be separated from the remaining areas of cap diaphragm 14 by an insulating trench 16, in order to achieve the electrical separation of electrode 6. Anchoring element 7 prevents electrode 6 from being completely undercut via insulating trench 16 and other perforations and thus from being detached from substrate 4. Positioning contact hole 9 and anchoring element 7 in different areas of electrode 6 spatially decouples the mechanical anchoring and the electrical connection, so that no complications are to be expected from the insulating trench.

The concept of the present invention for components made from SOI wafers allows for the mechanical anchoring of fixed structural elements such as electrodes, for example, to the substrate. This is achieved with the aid of anchoring elements which are introduced into the fixed structural elements and which are made of a material resistant to the etching of the sacrificial layer. In the case of an anchoring of electrodes, the anchoring material must also be electrically insulating, in order to allow for a spatial separation of anchoring and electrical contacting. Silicon-rich nitride or SiC have proven successful as anchoring materials.